EFDA EUROPEAN FUSION DEVELOPMENT AGREEMENT JET

PROGRESS IN TECHNOLOGY AT JET

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This paper reviews the work of many people from UKAEA, EFDA Close Support Unit and the EFDA Associations.

A Kaye, 16th ANS Topical Meeting on technology of Fusion Energy, Madison, Wisconsin, 14-16 September, 2004

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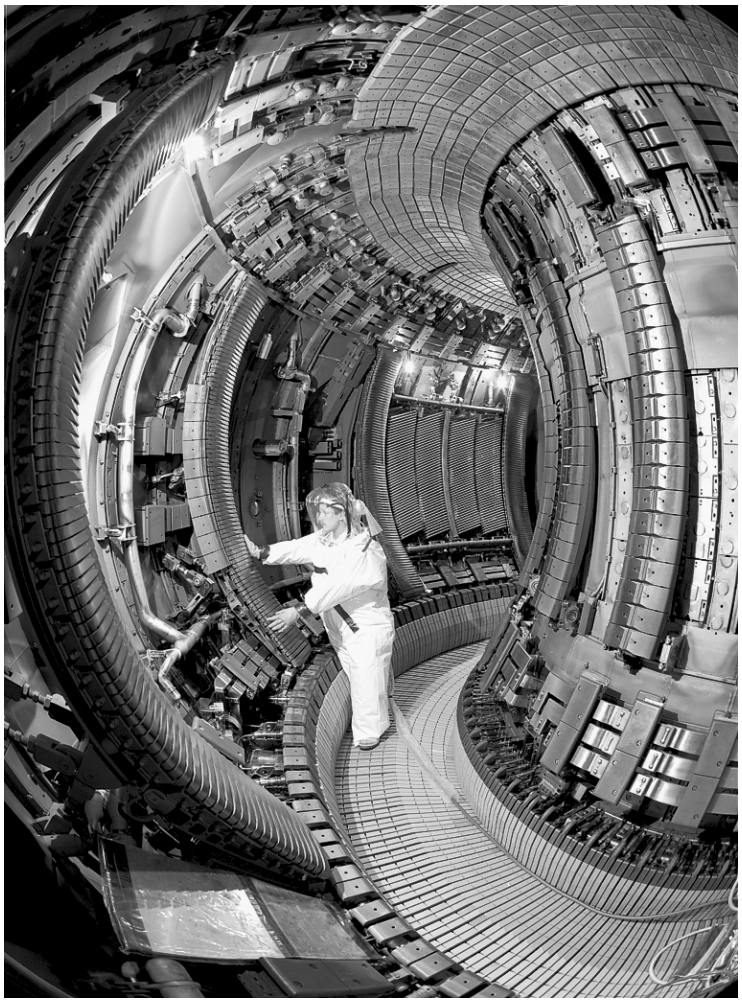
JET Operations



- **Unique ITER relevant capability :**

  Tritium operation / recycling
  Remote handling
  Beryllium
  Size (90m^3 plasma , 4 Tesla)
  NB,RF,LH,pellets,diagnostics….

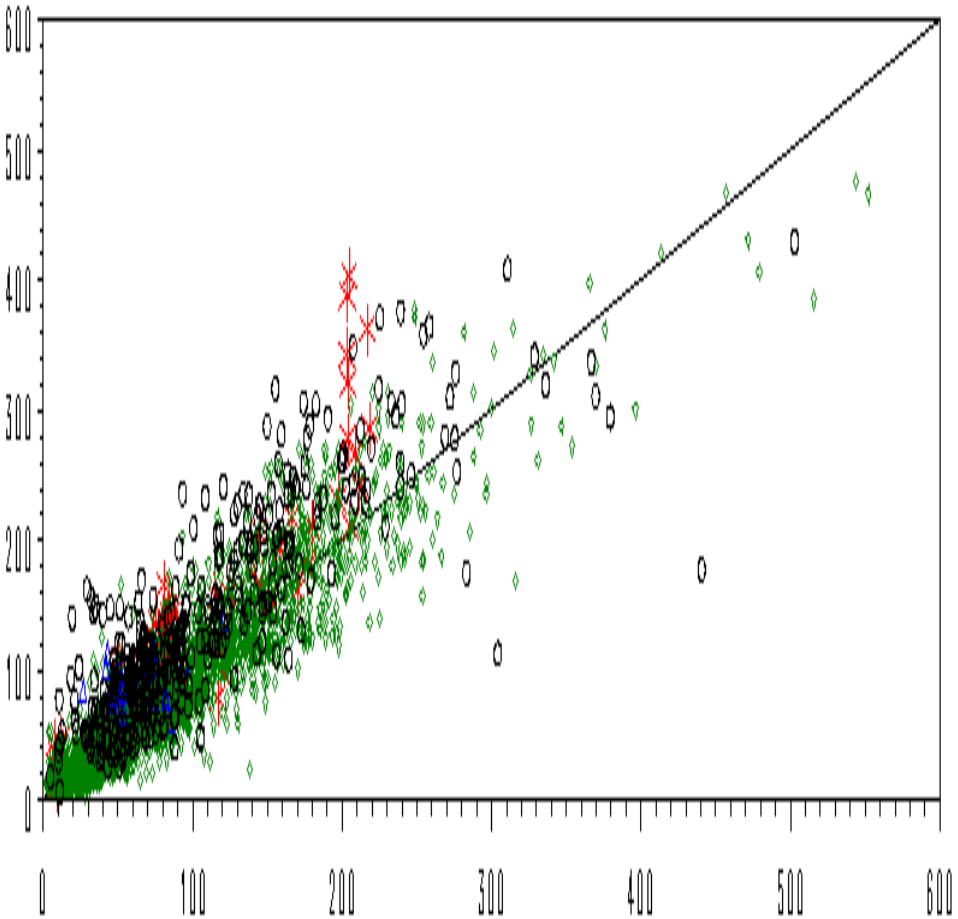
- **ITER-like high triangularity scenarios (>0 .47)**

  H=1, n=1.1 x n_G @ 2.5MA

- **Advanced ITB's, 'Steady state' scenarios…**

cf J Pamela, SOFT

Disruption Studies



Measure v. predicted vertical force (tonnes)

Highly shaped scenarios:
- High vertical forces (x2)
- Management controls

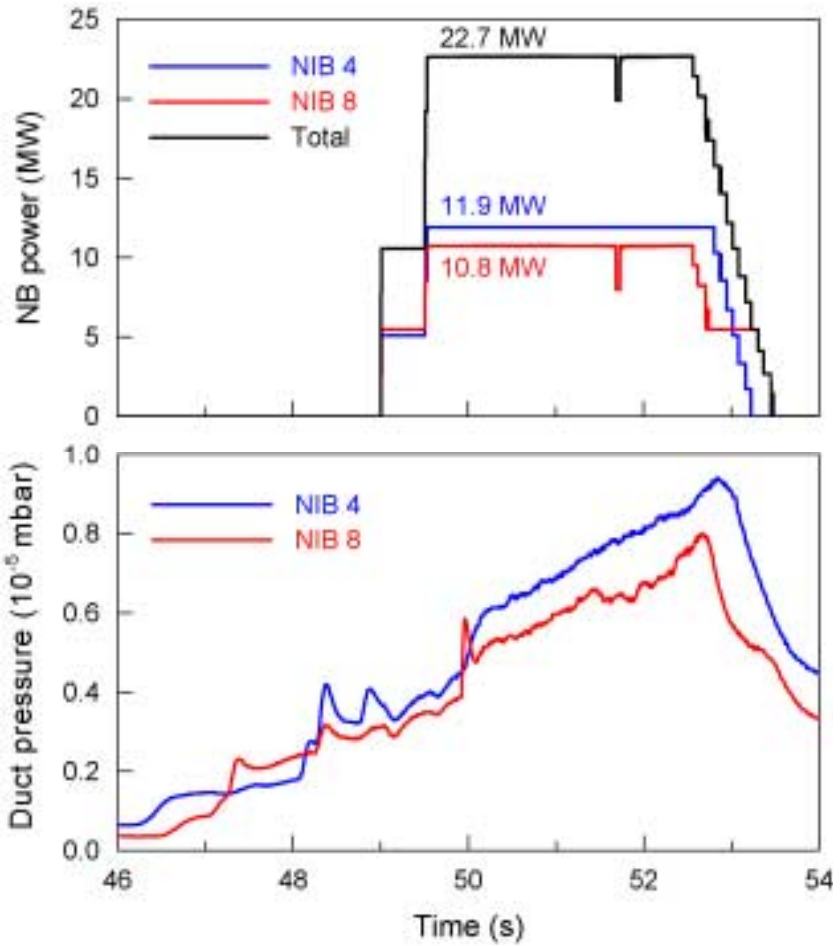
Energy quench:
- Flux to divertor and FW
- Good for ITER divertor!

Fast current quench scaling to ITER:
- c. 40ms independent of thermal stored energy

Diagnostic upgrade in hand:
- More halo probes
- Fast gas valve

cf V Riccardo

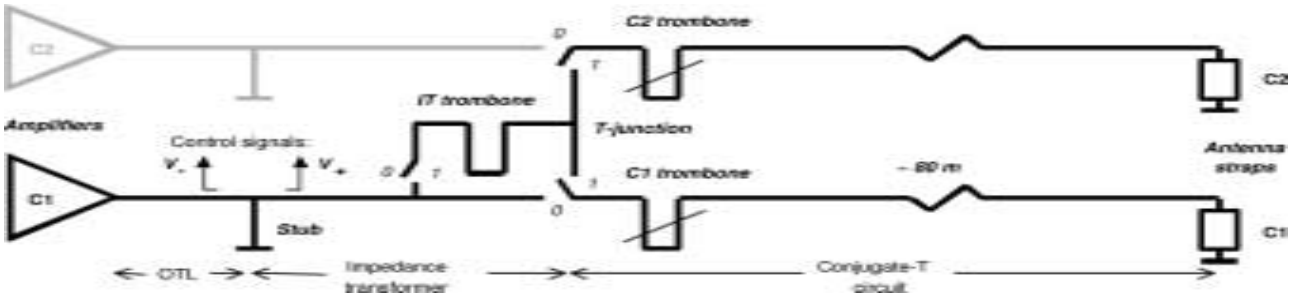
Recent Enhancements - NB Heating Power Upgrade



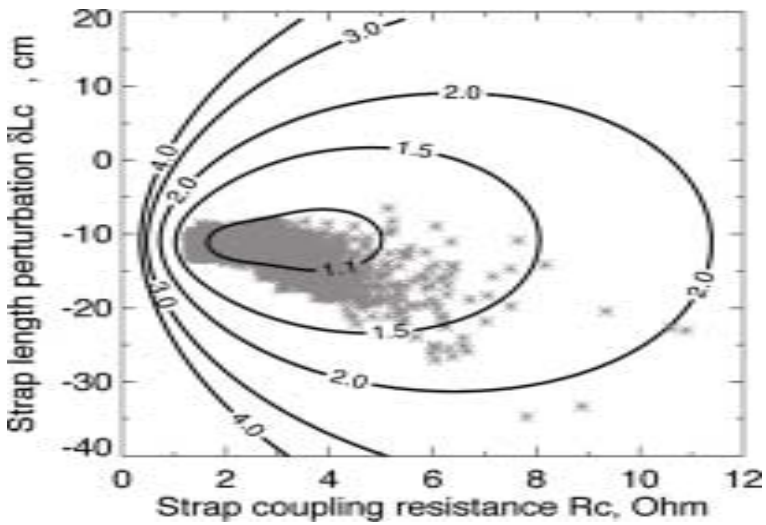
- New power supplies (2)
  130 kV x 130 A, switched mode
- New PINI accelerators to double current (to 60A)
- New beam scraper to handle increased power
- …….22.7 MW total NB injection
- Neutraliser modifications (cooled septum) being implemented to reach 25 MW potential

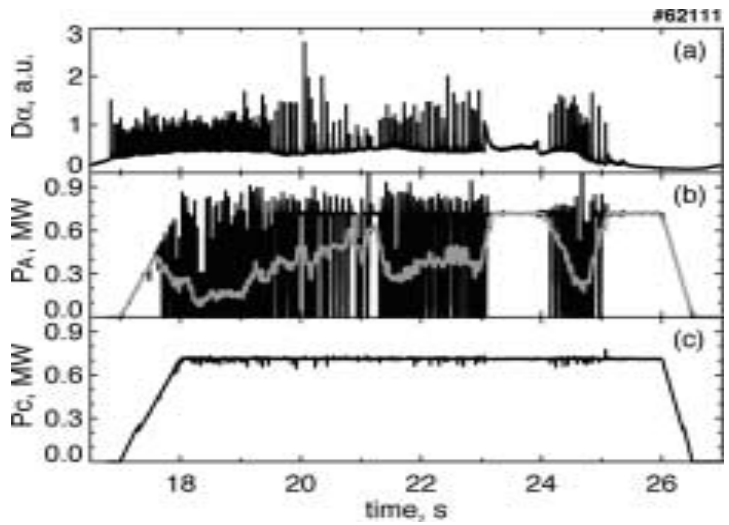
cf. D C Edwards,SOFT
D Ciric, SOFT

Conjugate-T Marching of RF Antenna



- Two A2 antenna straps connected with remote conjugate-T

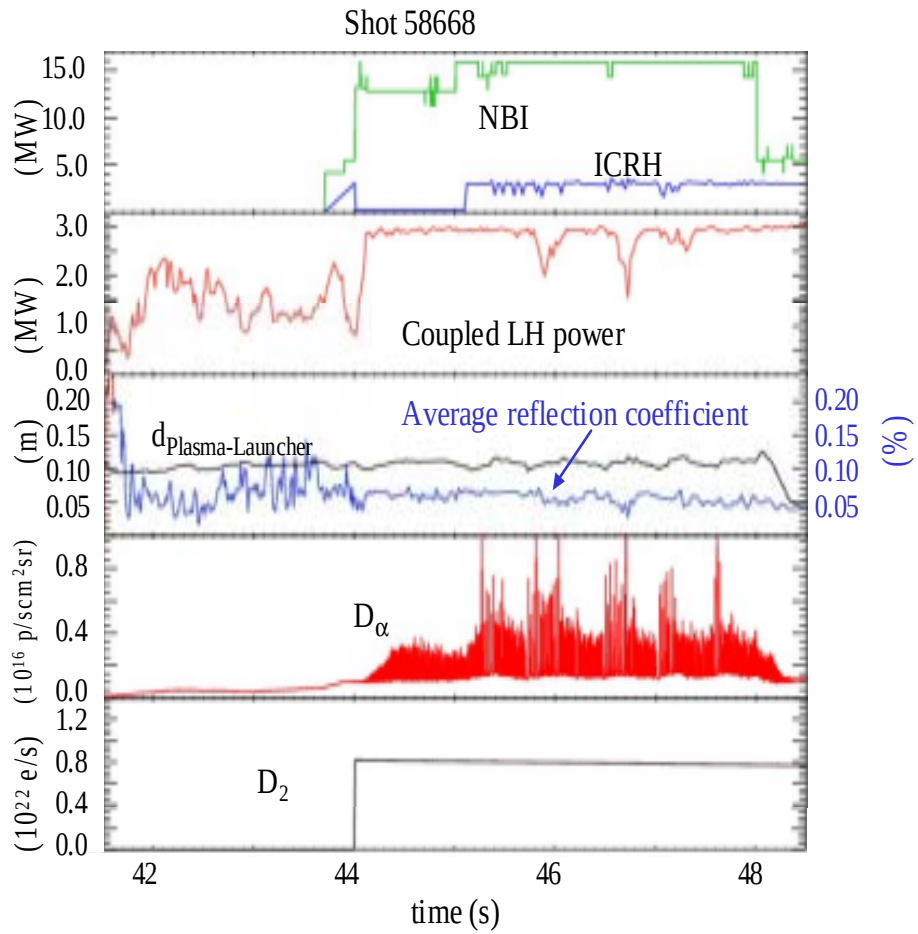




- VSWR remains below c. 1.5 at generator during ELMs

cf. I Monakhov, SOFT

LHCD Matching at ITER Relevant Gaps to the Separatrix



Good coupling /current drive efficiency at 100mm gap to separatrix

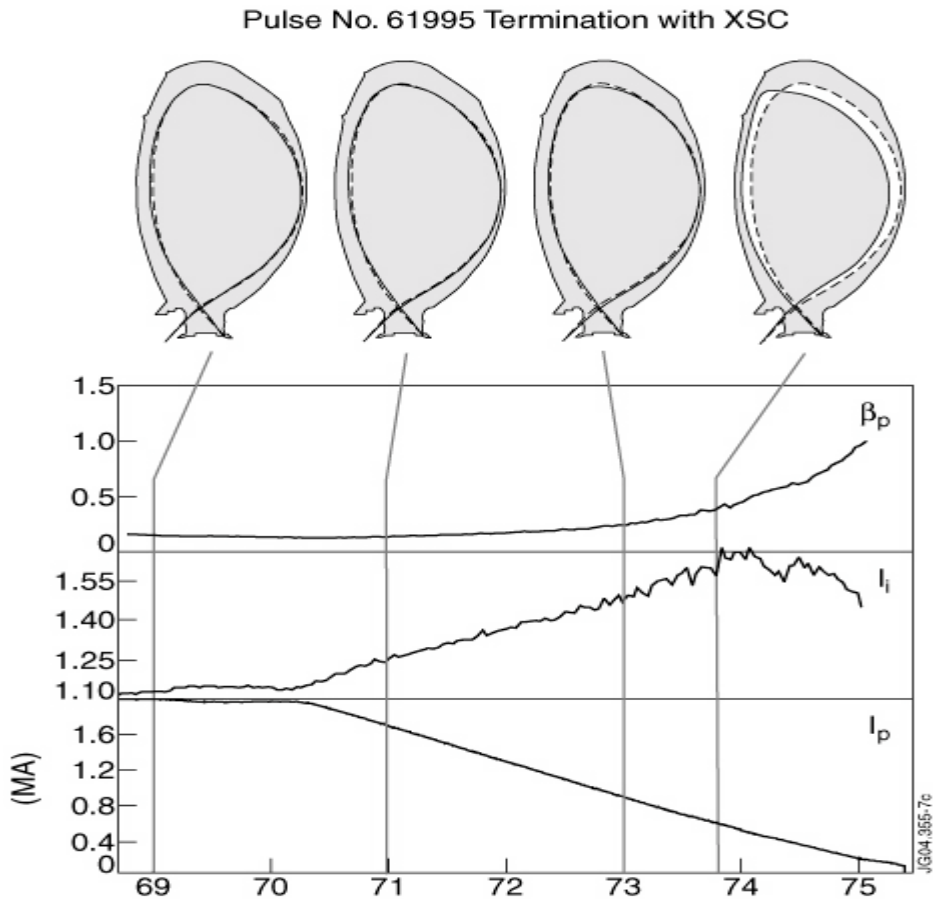
Gas puffing adjacent to launcher, effective with D_2 and CD_4 (cf also Tore Supra)

Sensitive to puffing location/rate (10^{22} elect/s)

Requires further understanding to allow extrapolation to ITER

cf. A Ekdahl, EPS
J Mailloux, IAEA

Extreme Shape Control



- Simultaneous control of up to 36 gaps to first wall
- Safe operation of highly shaped ITER-like scenarios

Pulse Termination of Highly Shaped Scenario using Extreme Shape Controller

cf. R Albanese, SOFT

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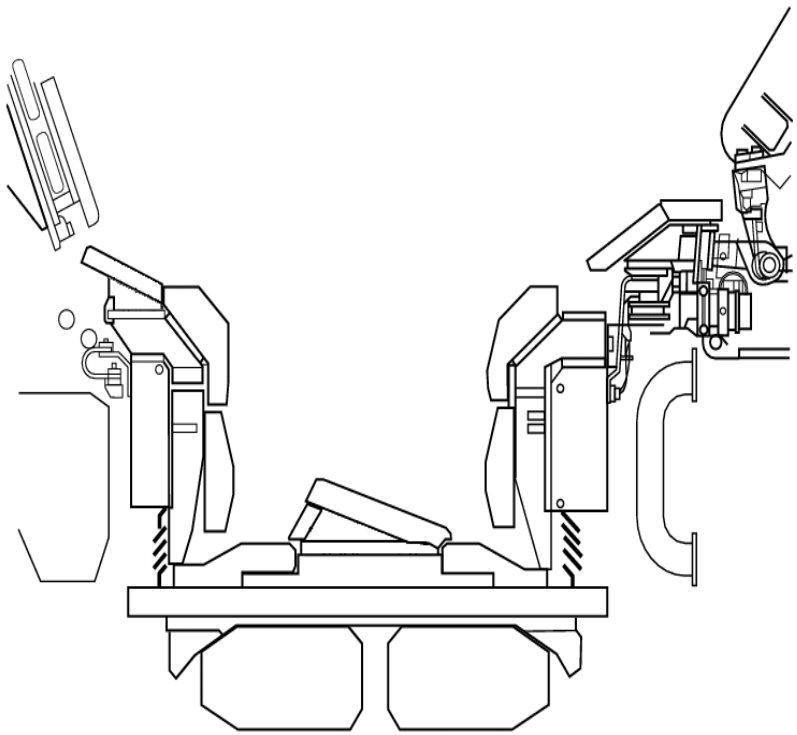
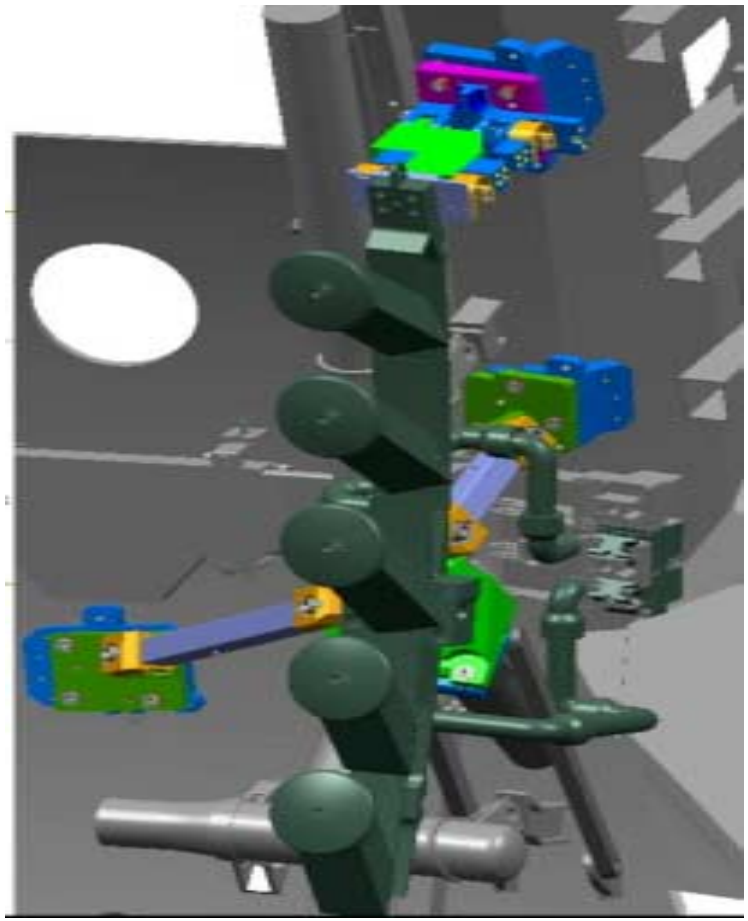
The JET 'EP' Enhancements: Divertor



- Load bearing divertor septum
- New inner protection tiles
- Refurbished magnetics/Langmuir probes/bolometer
- More halo probes

Allows ITER-like scenarios with increased lower triangularity (0.56) with strong additional heating (40MW for 10sec)

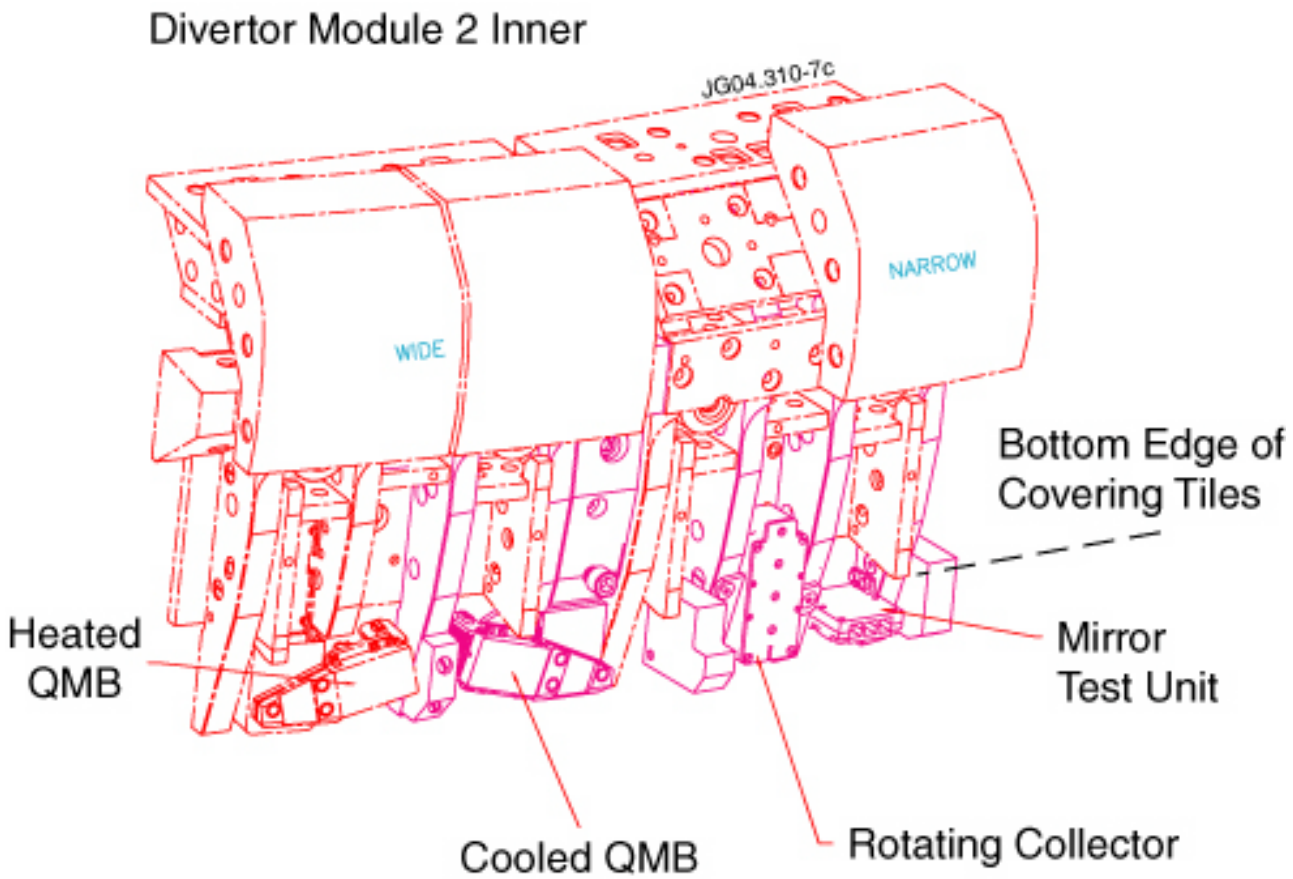
EP Diagnostic Enhancements



Lost Alpha Faraday Cup Array

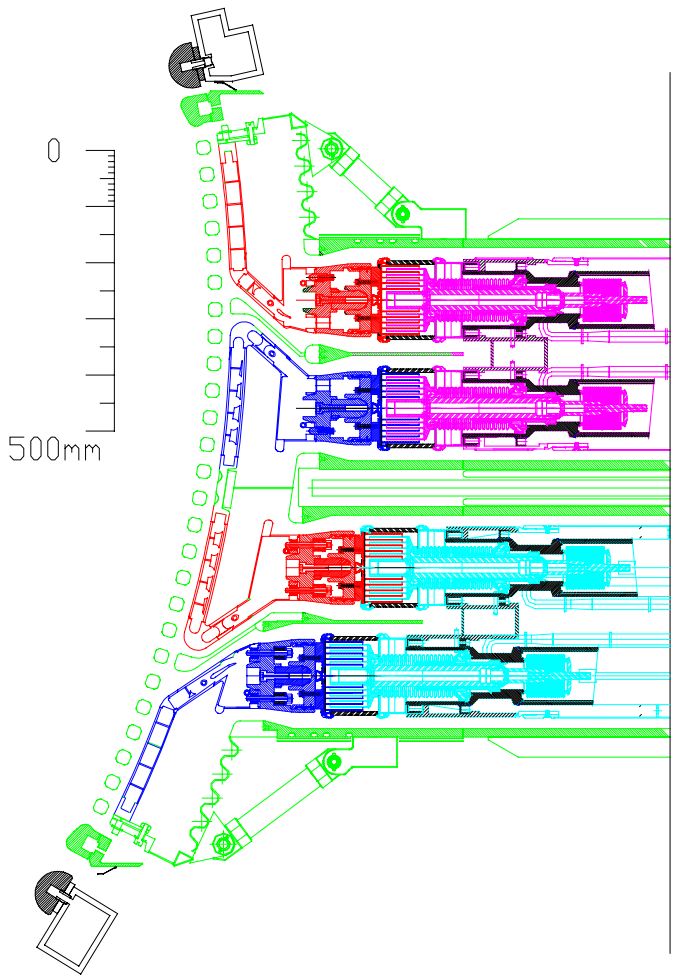
- Around 20 new or improved diagnostics - including burning plasma diagnostics (lost alpha and neutron detectors)
- Lost alpha diagnostics include Faraday cup array (from PPPL) and scintillator probe (from IPP)

EP Tritium Retention Diagnostics



- **Tritium related diagnostics being installed in the divertor**

EP ICRH Antenna



- New ITER-like ICRF antenna to be installed Nov 2005
- 8 short straps
- Internal conjugate-T matching
- Target: 7.5 MW coupled power , 30-55 MHz
- Matching and capacitors critical !

cf. F Durodie,SOFT

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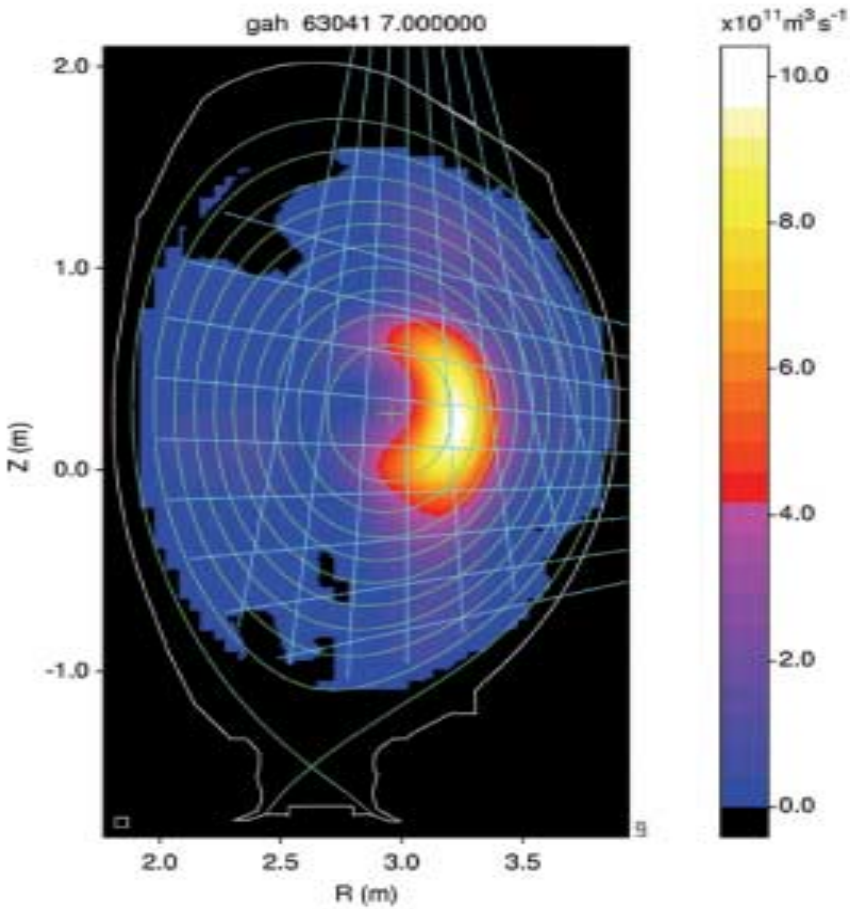
Trace Tritium Campaign

1- 3% tritium campaign with tritium NB injection implemented in autumn 2003

- **Limits to the Experiment**
  - 14 MeV neutron production: 10^{19} (320 μSievert/hr 4 months into shutdown)
  - Tritium to torus: 0.5 g
  - Tritium on torus cryopump: 0.7 g
- **Tritium Inventory**
  - Total of 5 g through machine (of which 4.5 g in NB, 2 ion sources)
  - Negligible additional tritium retained in torus after clean-up
- **Safety Issues**
  - Nearly equivalent to full tritium campaign
  - Prior review of safety case / approval by Safety Committee
  - Technical review of Key Safety Equipment - some upgrades
  - Extensive training of personnel

cf T T C Jones, Baden Baden

Alpha particle Localisation during a TTE Pulse



TTE PHYSICS OBJECTIVES

Study of :

- **Tritium transport**
- **Alpha particle dynamics**
- **Heating and current drive**

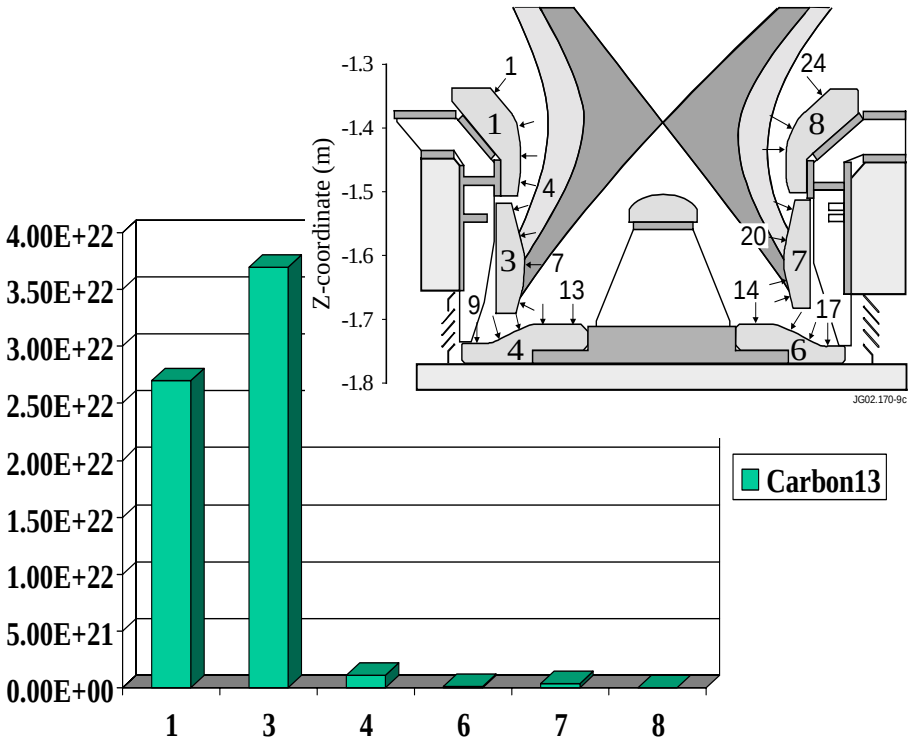
Using

- **80 ms Tritium gas puffs**
- **500 ms NB tritium injection**

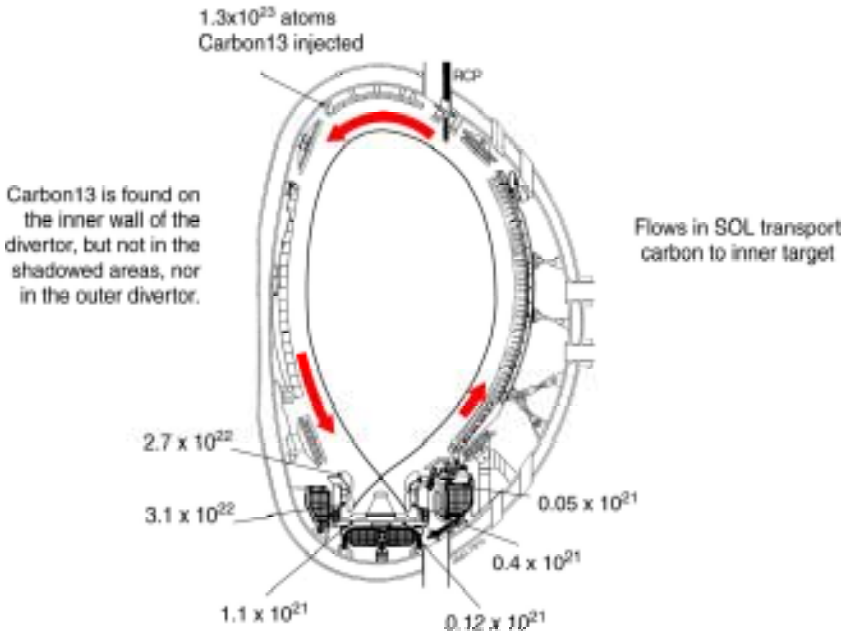
cf K-D Zastrow, EPS

Gamma emissivity from $^{9}Be(\alpha,n\gamma)^{12}C$

Tritium Retention



Transport of Carbon13 in the SOL



- Re-deposition on inner strike point/erosion at outer and FW (grad B drift up)
- Co-deposition of tritium at inner strike point; up to 1 TBq/g, surface area 4-7 m^2/g
- Some strongly bound in carbon matrix

cf P Coad, Baden Baden

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Tritium Technology

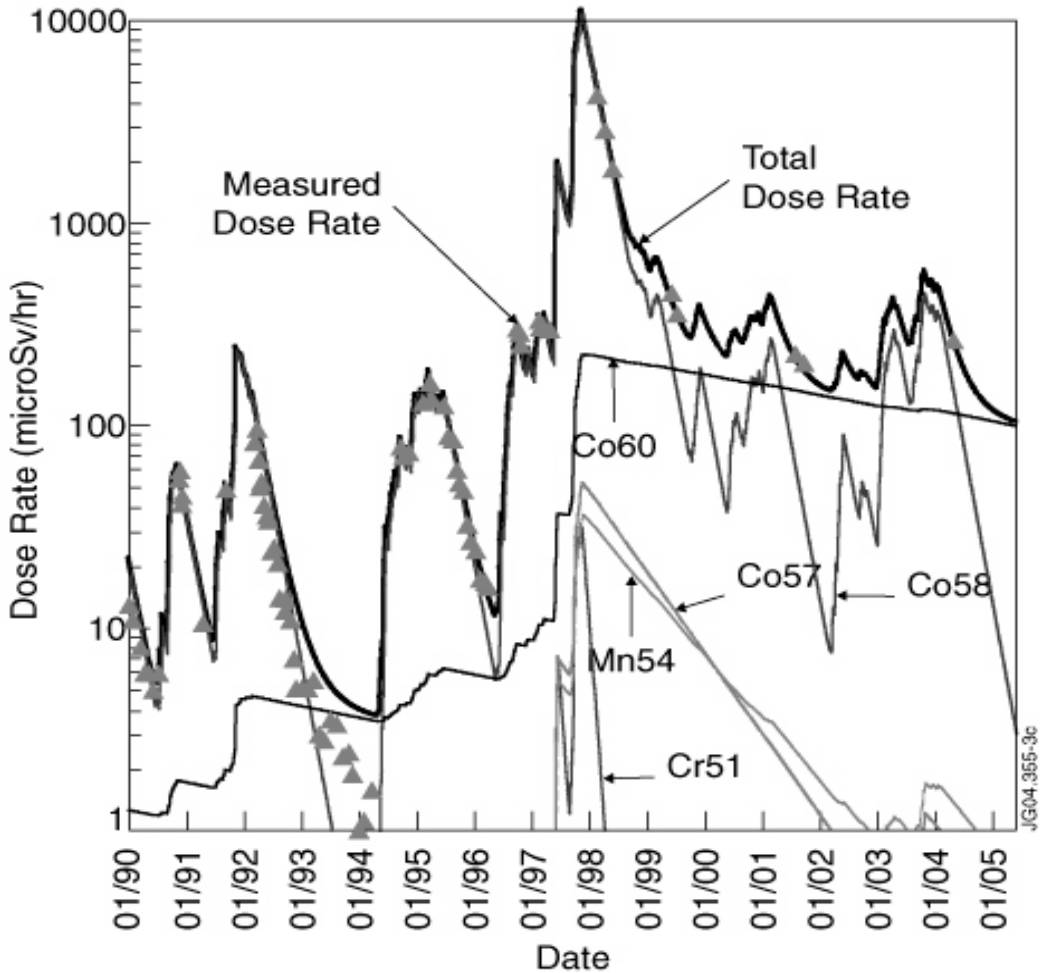
- **Detritiation**
  - Oxygen-methane flame effective at detritiation of CFC waste
  - Pulsed flash-lamp (300J x 10Hz) detritiation of carbon films on CFC tiles in-vessel being evaluated (including in-vessel demonstration)
  - Pulsed laser system for Carbon films is under development at KFK and PPPL
  - Water detritiation facility being optimised at FZK for use at JET
    Combined Electrolysis and Catalytic Exchange method
    10 tonnes throughput, 10^4 decontamination factor

- **Cryosorption Pumping**
  - ITER activated charcoal supercooled LHE panel supplied by FZK installed in JET tritium plant for study of tritium characteristics

- **Safety Issues**
  - Assessment of hazards of highly tritiated dust and flakes.
  - Cumulative experience in management of safety of a tritiated machine over an extended period

cf BADEN BADEN papers

JET Activation Since 1990



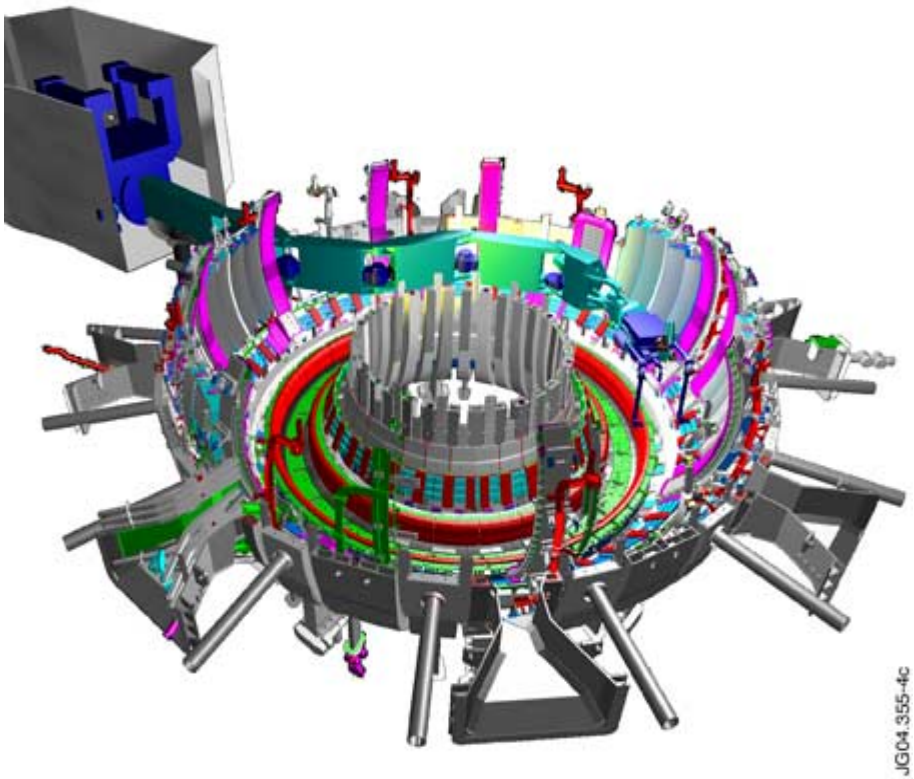
- **Dose rate at manned access June, 2004**

  260 μSievert/hr

of which long lived activation from DTE1 (Co 60, 5 year half life)

100 μSievert/hr

Remote Handling



- **Virtual reality**

Development of procedures/ training implemented largely using virtual reality software

- **Force feedback**

Force feedback to the operator from strain gauge transducers in the boom- load capability extended to load capacity of boom (400 kg)

Present shutdown has 10 months remote handling, 1 month manned access - 80% reduction in dose to c.40 man.milliSieverts.

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Conclusions

- JET has unique capability and contributes to ITER in many areas, both operations and technology
- Many enhancements have been implemented over the past five years, and continue to be implemented in the present shutdown
- JET contributes especially in Tritium technology, and has recently run a further trace tritium campaign
- JET has a strong remote handling capability which allows major enhancements to be implemented despite machine activation and tritium operations.